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An ammonia based gorwth scheme was developed to achieve large growth rates and high quality III-N materials. The benefits of isomorphic substrates were pointed out followed by the demonstration of GaN gorwth on ZnO substrates. The band discontinuities were determined, recognizing the strong piezoelectric effect. Other developments include: low resistance ohmic contacts, highly ideal shottlu barriers, large power density MODFETs, optically pumped stimulated emission to demonstrate the quality of the separate confinement heterostructures, and finally UV detectos with the lowest reported noise and high responsivity.

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Progress in Group III-Nitrides

Tremendous progress has been made in the deposition by MBE, processing and devices in regards to GaN and related heterostructures. We developed an ammonia based growth scheme to achieve large growth rates and high quality, pointed out the benefits of isomorphic substrates followed by the demonstration of GaN growth on ZnO substrates, determined the band discontinuities recognizing the strong piezoelectric effect, low resistance ohmic contacts, highly ideal Shottky barriers, large power density MODFETs and a MODFET model predicting the superb performance exhibited by MODFETs, optically pumped stimulated emission to demonstrate the quality of the separate confinement heterostructures, and finally UV detectors with the lowest reported noise and high responsivity. Each of these areas of research and progress is highligted below with abstracts of papers we have published.

Wook Kim, Özgür Aktas, Andrei Botchkarev, and Hadis Morkoç, "Reactive Molecular Beam Epitaxy of Wurtzite GaN Grown with Ammonia: Material Characteristics and Growth Kinetics", J. Appl. Phys. Vol. **79**, No. 10, pp. 7657-7666, (1996).

Abstract

High quality GaN by reactive molecular beam epitaxy (RMBE) with high growth rates(~2 μm/hr) employing ammonia gas as a nitrogen source is described. The high crystalline quality is evidenced by our recently reported modulation doped field effect transistors, GaN/AlGaN separate confinement heterostructures, GaN/AlGaN quantum wells, GaN epitaxial layers exhibiting only the intrinsic transitions, with even the second excited states of excitonic transitions visible, in the emission spectra, long excitonic lifetimes, and high quality Schottky contacts. The dependence of background carrier concentration and resistivity on substrate temperature is studied. The hexagonal nature of wurtzite GaN manifests itself as hexagonal features on the film, becoming as large as ~5 μm with facets at high growth temperatures such at 800 °C. For low V/III ratios, large hexagonal

hillocks, with highly strained regions on them, are formed due to the localized preferential growth. The photoluminescence (PL) characteristics of the films grown with low V/III ratio is studied. The PL spectra were analyzed to uncover the effect of substrate temperature on the films, and on the ground and excited state excitons. The influence of two competing factors, viz., thermal dissociation of ammonia and thermal desorption of Ga from the surface, on the growth kinetics was investigated.

G. A. Martin, S. T. Strite, A. Botchkarev, A. Agarwal, A. Rockett, W. R. L. Lambrecht, B. Segall, and H. Morkoç, "Valence Band Discontinuity Between GaN and AlN Measured by X-Ray Photemission Spectroscopy", Journal of Electronic Materials, APR, Vol. 24, N4, pp. 225-227.1995.

Abstract

The valence-band discontinuities at various wurtzite GaN, AlN, and InN heterojunctions were measured by means of x-ray photoemission spectroscopy. A significant forward–backward asymmetry was observed in the InN/GaN – GaN/InN and InN/AlN – AlN/InN heterojunctions. The asymmetry was understood as a piezoelectric strain effect. We report the valence band discontinuities for InN/GaN = 1.05 ± 0.25 eV , GaN/AlN = 0.70 ± 0.24 eV , and InN/AlN = 1.81 ± 0.20 eV , all in the standard type I lineup. These values obey transitivity to within the experimental accuracy. Tables of photoemission core level binding energies are reported for wurtzite GaN, AlN, and InN.

Z-Q. Fang and D. C. Look, W. Kim and Z. Fan, A. E. Botchkarev and H. Morkoç, "Deep centers in n-GaN grown by reactive molecular beam epitaxy", Appl. Phys. Lett. in press,

Abstract

Deep centers in Si-doped n-GaN layers grown by reactive molecular beam epitaxy have been studied by deep level transient spectroscopy along with their dependence on growth conditions. Si-doped GaN samples grown on Si-doped n+ GaN contact layers at 800 °C show a dominant trap

C_1 with an activation energy, E_T=0.44 eV and a capture cross section, σ_T=1.3 x 10^{-15} cm^{-2}, while samples grown at 750 °C on undoped semi-insulating GaN buffer layers show prominent traps D_1 and E_1, with E_T= 0.20 eV and σ_T=8.4 x10^{-7} cm^2, and E_T=0.21 eV and σ_T=1.6 x 10^{-14} cm^2, respectively. Trap E_1 is believed to be related to a N-vacancy defect since the Arrhenius signature of E_1 is very similar to the previously reported trap E, which is produced by 1-MeV electron irradiation in GaN grown by both metal-organic chemical vapor deposition and hydride vapor-phase epitaxy.

F. Hamdani, A. Botchkarev,H. Tang, W. Kim, and H. Morkoç "Effect of Substrate Surface Polarity and Buffer Layer on the Growth of GaN on ZnO by Molecular Beam Epitaxy" Appl. Phys. Lett., Vol. 71, pp. 3111-3114, (1997).

We present results on the effect of substrate surface polarity, O and Zn faces, on the quality of GaN epitaxial layers grown on ZnO(0001) substrates by reactive ammonia molecular beam epitaxy. The possible effects dealing with the disparity in surface preparation of the two faces have eliminated. Photoluminescence and reflectivity measurements demonstrate that the oxygen-face leads to higher quality GaN on ZnO compared to the zinc-face. We also present optical data obtained by using low temperature AlN, GaN and $In_xGa_{1-x}N$ buffer layers. The best result has been obtained with nearly lattice matched $In_{0.20}Ga_{0.80}N$ buffer layer.

H. Tang, W. Kim, A. Botchkarev, G. Popovici, F. Hamdani and H. Morkoç, "Analysis of Carrier Mobility and Concentration in Si-doped GaN Grown by Reactive Molecular Beam Epitaxy" Solid State Electronics, in press

Abstract

Quantitative information on acceptor concentration, donor concentration and donor activation energy has been obtained for Si-doped GaN epitaxial layers grown by reactive MBE through simultaneous fitting of the temperature dependent Hall mobility (μ) and carrier concentration (n) data. The analysis indicates that the electron mobility at high temperatures is significantly influenced by crystal defects. But the dominant scattering at low temperatures is by ionized impurities. Fitting the mobility data over a wide temperature range yields a good estimate of the acceptor concentration (N_A) in the sample which is then used as a known parameter in the fit to the n vs T data in order to determine the other important parameters, namely the donor activatio n energy (E_D) and donor concentration (N_D). Correct estimation of N_A is very important because the fitted value of E_D is very sensitive to the value of N_A. For a good fit, two donor levels had to be used in all the Si-doped GaN layers except in a sample grown at relatively lower temperature. The thermal activation energies of the shallower donor levels determined in different samples range from 4.5 meV to 8.9 meV, and are consistent with screened hydrogenic donors in GaN. The deeper levels are from 77 meV to 122 meV in different samples and not hydrogenic.

Zhifang Fan, S. Noor Mohammad, Wook Kim, Özgür Aktas, Andrei E. Botchkarev, and Hadis Morkoç, "Very low Resistance Multi-layer Ohmic Contact to n-GaN", Appl. Phys. Letts. Vol. 68, pp. 1672- 1674, (1996).

abstract

A new metallization scheme has been developed for obtaining very low ohmic contact to n-GaN. The metallization technique involves the deposition of a composite metal layer Ti/Al/Ni/Au (150Å/2200Å/400Å/500Å) on n-GaN preceded by a reactive ion etching (RIE) process which most likely renders the surface highly n type. Of the several attempts and with annealing at 900 °C for 30 sec, contacts with specific resistivity values of $\rho_s=1\times10^{-7}$ Ωcm^2 or lower for a doping level of 4×10^{17} cm^{-3} were obtained.

Sergei Ruvimov, Zuzanna Liliental-Weber, Jack Washburn, K.J. Duxstad and E.E. Haller, S.N. Mohammad, Z. Fan, and H. Morkoç, "Microstructure of Ti/Al and Ti/Al/Ni/Au ohmic contacts for n-GaN" Appl. Phys. Letts., Vol. 69, No. 11, pp. 1556-1558. September 9, (1996).

Abstract

Transmission electron microscopy has been applied to characterize the structure of Ti/Al and Ti/Al/Ni/Au ohmic contacts for n-type GaN (~10^{17} cm^{-3}) epitaxial layers.The metals were deposited either by conventional electron-beam or thermal evaporation techniques, and then thermally annealed at 900 °C for 30 sec in a N_2 atmosphere. Before metal deposition, the GaN surface was exposed to a reactive ion etching. A thin polycrystalline TiN layer epitaxially matched to the (0001) GaN surface was detected at the interface with the GaN substrate. This layer was studied in detail by electron diffraction and high resolution electron microscopy. The orientation relationship between the cubic TiN and the GaN was found to be: {111}TiN//{ 00.1}GaN, [110]TiN//[11.0]GaN, [112]TiN//[10.0]GaN. The formation of this cubic TiN layer results in a high excess of N vacancies
in the GaN close to the interface which is considered as the reason for the low resistance of the contact

S. N. Mohammad, Zhifang Fan, A. E. Botchkarev, W. Kim, Ö. Aktas, A. Salvador, and H. Morkoç, " Near Ideal Platinum-GaN Schottky Diodes " Electronics Letters, Vol. **32**, pp. 598 (1996).

Abstract

Fabrication and characterization of Pt/n-GaN Schottky barrier diodes are described. The n-GaN was grown by reactive molecular beam epitaxy method for the fabrication of these diodes. The capacitance-voltage (C-V) characteristics indicates marginal trap density in the semiconductor, and the current-voltage (I-V) characteristics give ideality factor very close to unity. Barrier height deduced both from I-V and C-V measurements are about 1.10 eV provided the influence of

scattering is considered negligible. This conforms again the near absence of interface traps in the diodes, and suggests that the effective mass of electron in GaN is 0.2.

F. Stengel, S. N. Mohammad and H. Morkoç, "Theoretical Characteristics of AlGaN/GaN MODFETs" J. Appl. Phys., Vol. 80 No. 5, pp 3031-3042, 1 September (1996).

abstract

A theoretical investigation of the electrical characteristics of GaN/$Al_xGa_{1-x}N$ (x is the Al mole fraction in AlGaN) MODFETs is carried out. Using a self-consistent solution of Schrödinger's equation and Poisson's equation, relations between the concentration of two-dimensional electron gas (2DEG), the Fermi level in GaN, and the average distance of the electrons from the heterointerface are calculated. A relation between the gate bias and the 2DEG concentration is obtained for a flat quasi Fermi level in AlGaN. Based on the relation between the 2DEG concentration and the applied gate bias a model for the drain current and the transconductance of the device is developed. The effects of the AlGaN thickness, the spacer layer thickness, the doping level, the aluminum mole fraction x, and the channel length L, are presented. Theoretical results are compared with the recent experimental data, which show striking agreement. The 2DEG concentration is found to be as high as 10^{13} cm^{-2}, and transconductance as high as 1,000 mS/mm. Finally, the effect of the difference in the properties of AlN and GaN, and a device structure that would take advantage of the bending of the quasi Fermi level for electrons in AlGaN, are discussed.

Özgür Aktas, W. Kim, Z. Fan. S.N. Mohammad, A. Botchkarev, A. Salvador, B. Sverdlov, and H. Morkoç "High Transconductance-Normally-Off GaN MODFETs", Electron. Letts. Vol. 31, No. 16, pp. 1389-1390, (1995).

Abstract

Normally off GaN based modulation doped field-effect transistors have been fabricated. The extrinsic transconductance of MODFETs with gate and channel lengths of 3 μm and 5 μm is as high as 120 mS/mm. The devices exhibit 300 mA/mm current at a positive gate bias of 3 V. This transconductance value compares very favorably with 45 mS/mm and 24 mS/mm reported earlier for 1 μm and 0.23 μm gate devices, respectively.

Z. Fan, S. N. Mohammad, Ö. Aktas, A. Botchkarev, A. Salvador, and H. Morkoç, "Suppression of Leakage Currents and Their Effect on the Electrical Performance of AlGaN/GaN MODFETs", Appl. Phys. Letts. Vol. 69 (9), pp. 1229-1231, 26 August (1996).

abstract

Electrical characteristics of high performance GaN MODFETs grown by reactive molecular beam epitaxy method are studied experimentally. The maximum measured drain-source current is 490 mA/mm which saturates at relatively low drain-source voltage V_{DS}. The transconductance increases with decreasing gate length reaching a value of 186 mS/mm in devices with a gate length of L_G=2 μm. Breakdown voltages of about 100 V have also been exbitied by devices with 2 μm gate lenghts and 1 μm gate to drain spacing. To our knowledge, this are the best values obtained so far from GaN MODFETs which we attribute to the suppression of leakage paths and improved materials quality.

Zhifang Fan, Changzhi. Lu , A. Botchkarev, H. Tang, A. Salvador, Ö. Aktas, W. Kim and H. Morkoç, "AlGaN/GaN Double Heterostructure Channel Modulation Doped Field Effect Transistors (MODFETs)", Electronics. Lett. Vol. 33, pp. 814-815 (1997) .

Abstract:

AlGaN/GaN double heterostructure channel modulation doped field effect- transistor (DHCMODFETs) with a 1 μm gate lengths and a 3 μm channel length exhibiting record transconductances and saturation current levels have been demonstrated. The maximum normalized

drain current and transconductance are about 1100 mA/mm and 270 mS/mm, respectively, at room temperature. Near pinch-off, the drain breakdown voltage is about 80 V. At an elevated temperatures of 300 °C, the maximum drain source current and extrinsic transconductance of the device is about 500 mA/mm and 120 mS/mm, respectively.

Ö. Aktas, Z. Fan, A. Botchkarev, , M. Roth, T. Jenkins, L. T. Kehias, and H. Morkoç, "Microwave Performance of AlGaN/GaN Inverted MODFETs", IEEE Elect. Dev. Letts. Vol. 18, pp 293-295,(1997).

Abstract

Microwave performance of inverted AlGaN/GaN MODFETs with 2 μm gate lengths and 78 μm gate widths is reported. Devices exhibited a normalized CW output power of 1.5 W/mm and PAE of 17.5 % at 4 GHz without catastrophic failure. These results are extraordinary considering the low current gain cut off frequency of 6 GHz which is a direct result of the long gate length. Inverted MODFETs exhibit reduced DC output conductance compared to normal MODFETs attesting that a part of the negative output conductance observed in nitride based FETs, which is often attributed to poor thermal conductivity of sapphire substrate, is due to carrier loss to the buffer layer at high fields. The electron mobility and sheet carrier concentration were 1450 cm^2/Vs (350 at room temperature) and 1.3 x 10^{13} cm^{-2} at 77K indicating that inverted interfaces in this class of heterostructures, unlike the GaAs/AlGaAs system, are comparable at this stage to the normal interface with the added advantage of barrier at the buffer layer side reducing the differential output conductance. Moreover, these together with other exciting results reported in the literature attest to the potential of nitride based heterostructures for high power applications.

T. J. Schmidt, X. H. Yang, W. Shan, J. J. Song, A. Salvador, W. Kim, Ö. Aktas, A. Botchkarev, and H. Morkoç, "Room-Temperature Stimulated Emission in GaN/AlGaN Separate Confinement Heterostructures Grown by Molecular Beam Epitaxy", Appl. Phys. Letts. Vol. 68, pp. 1820-18222, (1996).

abstract

We report the results of an optical pumping study of GaN/AlGaN separate confinement heterostructures grown on sapphire substrates by molecular beam epitaxy. Strong near ultraviolet stimulated emission was achieved at room temperature using a frequency- tunable nanosecond laser system with a side-pumping configuration. The pumping threshold for stimulated emission at room temperature was found to be ~90 kW/cm^2. The results suggest that the quantum confinement and waveguiding effects can substantially increase the quantum efficiency resulting in a significant decrease in the stimulated emission threshold.

G. Y. Xu, A. Salvador, W. Kim, Z. Fan, C. Lu, H. Tang, H. Morkoç, G. Smith, M. Estes, B. Goldenberg, W. Yang, and S. Krishnankutty, " Ultraviolet Photodetectors based on GaN p-i-n and AlGaN(p)-GaN(i)-GaN(n) Structures" Appl. Phys. Letts. Vol. 71, No. 15, pp. 2154-2156, (1997).

Abstract

We have investigated the spectral response of surface-illuminated GaN and AlGaN/GaN p-i-n ultraviolet photodetectors prepared by reactive molecular beam epitaxy (RMBE) on sapphire substrates. GaN homojunction p-i-n photodiodes exhibited a peaked response near the band edge. This enhanced response was absent in the AlGaN/GaN heterojunction p-i-n detectors. We analyzed the effect of p-layer thickness of the GaN p-i-n diodes on the magnitude of the peaked photoresponse. The AlGaN/GaN photodiodes had a maximum zero-bias responsivity of 0.12 A/W at 364 nm, which decreased by more than three orders of magnitude for wavelengths longer than 390 nm. A reverse bias of -10 V raised the responsivity to 0.12 A/W without any significant increase in noise. The root-mean-square(rms) noise current at 400 nm is ~1.0 pA corresponding to a noise-equivalent-power of ~8.3 pW.

G. Smith, M. J. Estes, D. Tang, A. Salvador, Z. Fan, G. Xu, A. Botchkarev, and. H. Morkoç, " Megahertz Bandwidth $Al_xGa_{1-x}N$/GaN- Based pin Detector" SPIE meeting, San Jose CA, January 25-28, 1998.

Abstract

This paper discusses recent results of time response and spectral responsivity measurements made on $Al_xGa_{1-x}N$/GaN-based p-i-n ultraviolet (UV) detectors with $0.03<x<0.12$, where x is the aluminum concentration. $Al_xGa_{1-x}N$/GaN-based p-i-n detectors with response times (1/e) as fast as 6 ns corresponding to greater than 26 MHz bandwidths are reported. Peak spectral responsivities of homojunction $Al_{0.03}Ga_{0.97}N$ p-i-n W detectors were found to be as high as 0.08 A/W at 343 nm while those of the $Al_{0.1}Ga_{0.9}N$ /GaN p-i-ns were as high as 0.15 A/W at 360 nm. Homojunction GaN and $Al_{0.03}Ga_{0.97}N$ as well as p-$Al_{0.1}Ga_{0.9}N$/i-GaN/n-GaN (heretofore referred to as $Al_{0.1}Ga_{0.9}N$/GaN) structures were grown on sapphire substrates by reactive molecular beam epitaxy (MBE) and processed into UV detectors. These p-i-n detectors were then characterized in terms of their time response and spectral responsivity. Attempts to measure the noise of the $Al_{0.03}Ga_{0.97}N$ homojunction p-i-ns are also discussed.

List of Publications in Nitrides Resulting from the AFOSR Support

Book: H. Morkoç, "Wide Bandgap Nitrides and Devices", Springer, in press.

Edited: G. Pensl, H. Morkoç, B. Monemar and E. Janzén, " Proceedings of the Internatioal Conference on Silicon Carbide, III-Nitrides and Related Materials,ICSC III-N, '97, Stockholm, Sweden, Aug. 31, 1997. Materials Science Forum Vols. 264-268, Trans Tech Publication Ltd. ISSN 0255-5476

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Progress Made in MIS-Like Structures

The key ingredient for the success of Si based electronic devices is the MOSFET made possible by the native dielectric having a high field strength, large bandgap, low bulk trap concentration which forms a high quality. MOSFETs have low gate leakage and allow complementary devices for low power consumption. Compound semiconductors lack such a dielectric. In its place, other dielectrics such as SiO_2, Si_3N_4, Al_2O_3, GaS, Ga_2O_3($Gd_3Ga_5O_{12}$), oxidized AlAs, oxidized Al, have been attempted. However, inversion FETs have not been achieved. Use of Si interlayers followed by SiO_2 appears attractive and has been explored by several groups. In order to avoid any possible oxidation of the GaAs surface we have used Si_3N_4 as the insulator with a Si interface layer and obtained interface state densities in the mid to high 10^{10} $cm^{-2}eV^{-1}$ in both n- and p -type capacitors on a regular basis. This effort has recently led to self aligned/accumulation with n-channel MISFETs with 2.2 μm gate lengths which exhibited transconductances of 170 mS/mm, and inversion n-channel MISFETs, albeit with low transconductances, part of which can be attributed to inferior device topography and processing. Progress has been made to remedy the apparent shortcomings of the fabrication related issues as well as the possible unfavorable outcome of the strain between Si ands (100) GaAs.

An in-depth investigation of growth and characterization of GaAs based metal-insulator-semiconductor structures with strained hetero-interlayers afforded by a multi-chamber deposition system has been undertaken. The novel heteroepitaxial interlayers employed between Si_3N_4 dielectric and GaAs semiconductor were Si, Si/$Al_{0.3}Ga_{0.7}As$, Si/GaP, Si/Ge, and Si/$In_{0.05}Ga_{0.95}As$. Electrical measurements examining the insulator/ semiconductor interface were complemented by reflection high electron energy diffraction, scanning tunneling microscopy, and x-ray photoelectron spectroscopy as well as spectroscopic ellipsometry measurements. The effort culminated in the attainment of interface trap densities near mid 10^{10} eV^{-1} cm^{-2}, which is the lowest values ever reported, on both n- and p-type GaAs MIS structures. This has allowed the realization of accumulation mode with high transconductance GaAs metal-insulator-semiconductor field-effect transistors (MISFETs) having a maximum transconductance approaching 170 mS/mm as well as inversion mode MISFETs.

Utilizing an *in situ,* low temperature deposition utilizing both chemical vapor deposition and molecular beam epitaxy, an insulator/semiconductor interface of exceptional quality has been achieved. A minimum interface state density from a Si_3N_4/Si structure is $2x10^{10}$ eV^{-1} cm^{-2} near Si midgap was obtained in a GaAs-based MIS heterostructure. Typical interface trap densities of $5x10^{10}$ eV^{-1} cm^{-2} were realized at Si_3N_4/GaAs(001) interfaces with accurate control of the interfacial Si thickness. Furthermore, promising interface properties of MIS diode gated on GaAs(111)B surface have been achieved with minimum interface state densities in the high 10^{10} eV^{-1} cm^{-2} range, which is likely to be possible even on pre-patterned GaAs(100) substrates. The low density of surface states as well as the presence of 1 MHz C-V curves at liquid nitrogen temperatures confirm the realization of an unpinned GaAs surface Fermi level.

The thermal stability of Si_3N_4/Si/GaAs interfaces after high temperature annealing were examined via electrical methods, XPS and spectroscopic ellipsometry measurements uncovered interface degradation in samples subjected to heat treatments above 750 °C. It was found that a reduction in the Si interlayer thickness took place during the deposition of silicon nitride, which is most likely caused by outdiffusion of Ga, thus degrading the Si_3N_4/Si/GaAs interfaces. An employment of Si and wider bandgap materials such as $Al_{0.3}Ga_{0.7}As$ and GaP in between Si_3N_4 and GaAs enhanced the total band bending of insulator/semiconductor interface about 0.2 eV, which modifies the band discontinuity of the Si_3N_4/Si/GaAs interfaces. Interface trap densities of $< 1.1 \times 10^{11}$ eV^{-1} cm^{-2} are obtained from Si_3N_4/Si/$Al_{0.3}Ga_{0.7}As$/GaAs and Si_3N_4/Si/GaP/GaAs interfaces and the thermal stability of the latter structure was found to be less degraded compared to that of Si_3N_4/Si/GaAs interfaces.

Minority-carrier generation and recombination kinetics of Si_3N_4/GaAs MIS structures with Si and Si/Ge interlayer were studied via temperature-dependent C-V measurements. An activation energy (E_a) of 0.7 eV and 0.68 eV from the p-GaAs and n-GaAs MIS structures was obtained, indicating

that the recombination of the minority-carriers take place through the bulk traps in the GaAs midgap. On the other hand, the E_a of 0.58 eV from the Si_3N_4/Si/Ge/n-GaAs MIS structures suggested that the activation energy is 0.13 eV smaller than half the bandgap energy of GaAs due to the Ge interlayer.

Using Si/$In_{0.05}Ga_{0.95}As$ interlayers, improved FET performance over Si_3N_4/Si/GaAs structure was attained. Self-aligned gate depletion mode $In_{0.05}Ga_{0.95}As$ metal-insulator-semiconductor field-effect-transistors (MISFETs) having 3 mm gate lengths exhibited field-effect bulk mobility of 1400 cm^2/Vs and transconductances of about 170 mS/mm. Realization of such a high transconductance for a device with relatively large channel length attests to the suitability of InGaAs channel in MISFETs. Due to high electron mobility of $In_{0.05}Ga_{0.95}As$ and low gate leakage current of MIS structure, this material system has the potential for an extremely high performance low power metal insulator semiconductor technology. Utilizing a re-growth scheme, n-channel Si/GaAs MISFETs have been fabricated with about 2 μm gate lengths which demonstrated transistor action.

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